Case Studies of Land Atmosphere Interaction within the 12 km North American Land Data Assimilation System (NLDASE) Project

Charles J. Alonge and Brian A. Cosgrove – SAIC and NASA GSFC Hydrological Sciences Branch

Collaborators: Paul R. Houser, CREW; Kenneth E. Mitchell, Michael Ek, Keith Brill, and Eric Rogers; NOAA/NCEP/EMC

NLDASE Project Overview

Land surface conditions from uncoupled LSMs forced by observations are free from many of the biases which affect closed, coupled systems, and are well-suited for NWP model initialization. The NLDASE project seeks to assess the impact of such initialization on NCEP's 12km coupled workstation Eta model (Black, 1994). Featuring multiple LSMs and assimilating multiple land surface quantities, this system will serve to supply the Eta model with accurate, unbiased and uncoupled initial land surface conditions on its native Arakawa E grid. Project components include: 1) Generation of land surface states over the North and Central American domain, with and without application of land data assimilation techniques, 2) Initialization of the NCEP workstation Eta model with uncoupled NLDASE states and internally cycled Eta land surface states, 3) Execution of ensemble model runs using NLDASE and Eta modeling system.

Eta Model Initialization

•Experiments are assessing the impact that NLDASE initialization of Eta model land surface states has on short- to medium-range forecasts (Figure 1)

•Validation of Eta model forecasts is occurring over the standard NCEP Forecast Verification System (FVS) (Brill, 1999) regions pictured in Figure 2.

•*All initial atmospheric conditions and boundary conditions are identical between NLDASE Eta model simulations. The only difference lies in the initial land surface conditions that are used* ***(LIS1, LIS3, LIS5, LIS6, and NCEP or LIS0*** *runs discussed below)*

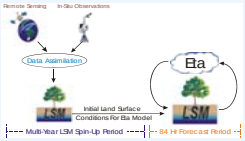


Figure 1. NLDASE initialization strategy. Forced by observation and model-based data, and constrained by data assimilation, NLDASE generated several years of land surface output which was used to initialize the Eta model's land surface states.

Land Surface Modeling Component

• NLDASE research is based at NASA GSFC with support from NOAA NCEP

•Hourly, uncoupled Noah LSM output was generated on the 12km Arakawa E grid used by the operational Eta model for the period from 2000-2003

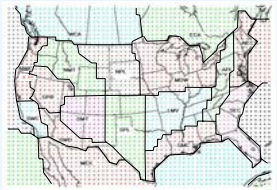


Figure 2. Validation of NLDASE Eta simulations is performed over the standard NCEP Forecast Verification System (FVS) regions pictured above.

NLDASE Benchmarking Effort

• An ongoing benchmarking effort seeks to determine the impact on Eta model forecasts of using initial land surface conditions from four different NLDASE-Noah LSM simulations:
- **LIS1** run--with NLDASE forcing (Control Run)
- **LIS3** run--with NLDASE forcing and MODIS snow cover assimilation (10 mm update amount)
- **LIS5** run – LIS1 run scaled to EDAS climatology (2000-2003)
- **LIS6** run – LIS3 run scaled to EDAS climatology (2000-2003)

• Scaling performed by matching the CDF of the NLDASE soil moisture states to the CDF of the EDAS soil moisture states (Reichle and Koster, 2004)

• Comparisons are performed against Eta model forecasts produced with **NCEP** operational initial land surface conditions (Figure 3)

• The benchmark covers May 1-10, 2003, which featured a massive severe weather outbreak over the central and eastern United States (details of event can be found in Hamill et al. (2005)

• A total of 100 Eta model runs were conducted out to 84 hours (5 sets of initial conditions, 2 cycles per day for 10 days)

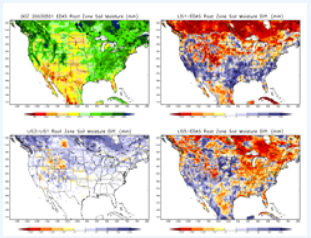


Figure 3. Sample EDAS root zone soil moisture (mm) field (upper left) and associated root zone soil moisture differences between EDAS and the NLDASE uncoupled simulations.

Benchmarking Results

All Surface Forecasts

	LIS1 2m T	LIS3 2m T	LIS5 2m T	LIS6 2m T	LIS1 2m RH	LIS3 2m RH	LIS5 2m RH	LIS6 2m RH
00Z East Bias	13.72	21.05	-0.21	4.01	56.59	78.21	-4.27	1.07
00Z West Bias	10.94	16.12	9.22	11.51	12.91	14.90	11.47	11.37
12Z East Bias	-0.31	7.22	-10.64	-11.15	42.64	65.36	-4.16	1.26
12Z West Bias	6.63	12.11	4.39	-0.12	14.43	17.02	13.87	13.15
00Z East RMSE	2.31	2.44	0.80	0.67	4.49	4.51	2.60	2.47
00Z West RMSE	1.66	2.36	1.49	1.71	4.72	5.45	5.09	5.03
12Z East RMSE	2.42	3.09	0.52	0.11	5.28	5.38	2.94	2.99
12Z West RMSE	1.60	2.26	1.79	1.69	5.61	6.34	6.05	6.40

Table 1. Percent improvement in bias and RMSE of LIS1, LIS3, LIS5, and LIS6 runs versus control simulation for 2m temperature (2m T), 2m and relative humidity (2m RH). Warmer colors indicate improvements.

All Precipitation Forecasts

	LIS1 24-48H	LIS3 24-48H	LIS5 24-48H	LIS6 24-48H	LIS1 0-84H	LIS3 0-84H	LIS5 0-84H	LIS6 0-84H
East Bias	5.106	6.809	-5.379	-6.753	4.018	5.804	4.231	3.612
West Bias	-4.139	1.525	-10.710	-30.195	-87.649	-52.941	-10.971	-40.720
East ETS	-0.245	0.000	0.175	0.183	0.125	0.000	0.369	0.515
West ETS	0.717	0.598	0.547	-1.330	0.236	-1.885	0.222	-1.635
East FAR	-0.813	-0.325	0.652	0.803	0.168	0.000	1.126	1.748
West FAR	0.156	-0.313	0.024	-5.520	-0.464	-6.646	-0.293	-6.024
East POD	-0.157	0.315	0.429	0.135	0.162	0.162	0.737	0.761
West POD	2.384	1.964	1.435	2.393	0.683	0.820	0.645	0.940

Table 2. Percent improvement in bias, equitable threat score (ETS), probability of detection (POD), and false alarm ratio (FAR) scores of LIS1, LIS3, LIS5, and LIS6 runs over control simulation for 24-48 hour, and 0-84 hour forecast periods.

Selected Case Studies From Benchmarking Period

The NCEP FVS results from the entire 10-day benchmarking period indicated that the surface temperature and relative humidity fields were most sensitive to the use of uncoupled NLDASE land surface states (Table 1), while the impact on precipitation forecasts was mixed and generally small (Table 2). A selection of individual forecasts are presented to highlight the impacts that NLDASE initialization has on individual Eta forecasts of surface temperature, relative humidity, precipitation, radiation, and severe weather guidance. Sources of data utilized in this study are surface observations (land and water) from the Global Telecommunications System (GTS), Climate Prediction Center (CPC) Daily Precipitation Analyses (Higgins et al., 2000), GOES downward shortwave radiation data, and severe weather reports from NOAA's Storm Prediction Center (SPC).

Eta Forecasts Initialized 12Z May 3rd 2003

FVS and Radiation Evaluation

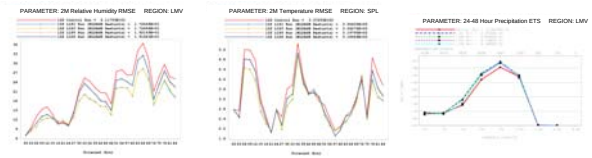
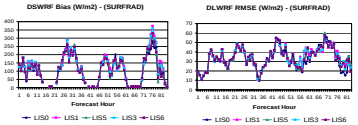


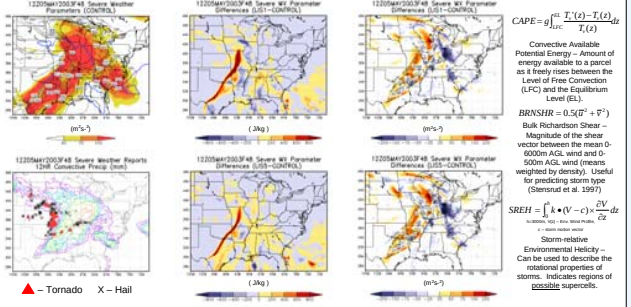
Figure 4. FVS output for all five Eta forecasts initialized on 12Z May 3, 2003. From left to right:, 2m Relative Humidity RMSE in the LMV verification region, 2m Relative Temperature RMSE in the SPL verification region, and 24-48 Hour ETS in the LMV verification region. NLDASE initialized forecasts showed improvements in 2m temperature and relative humidity fields. This resulted in better forecasts of precipitation in in the severe weather outbreak regions.



GOES	LIS0	LIS1	LIS5	LIS3	LIS6
DSWRF BIAS	140.64	138.97	135.80	138.61	136.03
DSWRF RMSE	310.37	310.53	307.81	310.15	307.92
SURFRAD					
DSWRF BIAS	114.83	121.98	112.70	119.65	113.24
DSWRF RMSE	155.14	160.16	152.37	158.41	153.77
DLWRF BIAS	-20.16	-19.81	-19.92	-19.72	-19.73
DLWRF RMSE	34.03	34.02	33.93	33.76	33.71

Figure 5. From left to right: Downward shortwave radiation flux bias for all experiments. Downward longwave radiation flux RMSE for all experiments. Summary statistics of BIAS and RMSE for both the GOES and SURFRAD evaluations of NLDASE and ETA radiation forecasts (in W/m²).

Severe Weather Guidance



Description of Parameters

$$CAPE = g\int_{LFC}^{EL}\frac{T_v(z)-T_e(z)}{T_e(z)}dz$$

Convective Available Potential Energy – Amount of energy available to a parcel as it freely rises between the Level of Free Convection (LFC) and the Equilibrium Level (EL).

$$BRNSHR = 0.5(\bar{U}^2+\bar{V}^2)$$

Bulk Richardson Shear – Magnitude of the shear vector between the mean 0-6000m AGL wind and 0-500m AGL wind (means weighted by density). Useful for predicting storm type (Stensrud et al. 1997)

$$SREH = \int_0^h k\bullet(V-C)\times\frac{\partial V}{\partial z}dz$$

Storm-relative Environmental Helicity – Can be used to describe the rotational properties of storms. Indicates regions of possible supercells.

Figure 6. Upper Left Panel: Fields of BRNSHR (m^2s^{-2}), SREH(m^2s^{-2}), and CAPE from the control run. Thick solid line (blue) indicates where CAPE above 200J/kg (to the south of the line). Values of BRNSHR are shaded and SREH is contoured every 100 m^2 s^{-2}. Bottom Left Panel: 12 hr total of convective precipitation and severe weather reports valid on 12Z 5 May 2003. Middle Panels: Differences in CAPE simulated between two NLDASE forecasts and the control run. Rightmost Panels: Differences in SREH (shaded) and BRNSHR (contoured) between two NLDAS forecasts and the control run.

Eta Forecasts Initialized 12Z May 9th 2003

FVS and Radiation Evaluation

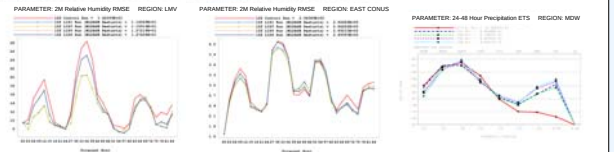
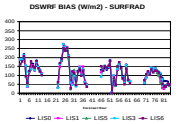


Figure 7. FVS output for all five Eta forecasts initialized on 12Z May 9, 2003. From left to right:, 2m Relative Humidity RMSE in the LMV verification region, 2m Relative Humidity RMSE in the Eastern Conus verification region, and 24-48 Hour ETS in the MDW verification region. Similar to Figure 4, the NLDASE initialized forecasts showed improvements in 2m temperature and relative humidity fields. This resulted in better forecasts of heavier precipitation amounts in in the severe weather outbreak regions.



GOES	LIS0	LIS1	LIS5	LIS3	LIS6
DSWRF BIAS	121.49	119.35	118.66	119.59	118.40
DSWRF RMSE	307.12	306.41	304.25	305.81	303.94
SURFRAD					
DSWRF BIAS	121.23	117.13	116.70	118.35	118.21
DSWRF RMSE	142.78	141.47	137.48	142.81	138.32
DLWRF BIAS	-16.28	-14.96	-16.15	-14.83	-16.05
DLWRF RMSE	28.10	27.51	28.18	27.43	28.11

Figure 8. From left to right: Downward shortwave radiation flux bias for all experiments. Downward longwave radiation flux RMSE for all experiments. Summary statistics of BIAS and RMSE for both the GOES and SURFRAD evaluations of NLDASE and ETA radiation forecasts (in W/m²).

Severe Weather Guidance

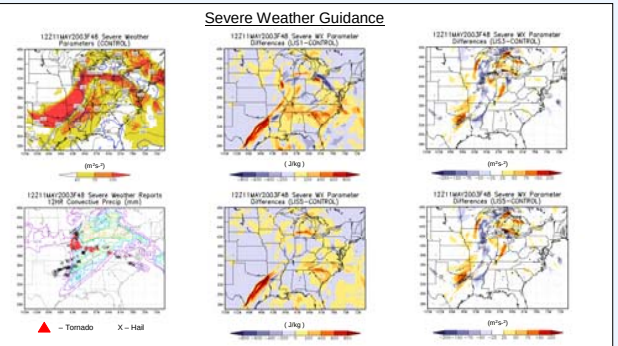


Figure 9. As in Figure 6 except from 12Z 11 May 2003. The NLDASE forecasts outline larger areas of positive CAPE in the severe weather outbreak region. However, the NLDASE forecasts also portray reduced values of SREH and BRNSHR severe weather area.

Summary

• Large differences emerge between the NLDASE initialized forecasts and the control forecast when examining individual forecasts

• Surface temperature and relative humidity frequently benefited from the uncoupled initialization approach

• In general, the largest differences in forecasts came between the NLDASE simulations as a whole and the control forecast

•Scaling of the initial land surface conditions to the EDAS climatology generally degraded the skill of the forecasts (LIS5 and LIS6)

• NLDASE forecasts performed better than the control with respect to forecasts of downward longwave and shortwave radiation fluxes

• The timing and magnitude of synoptic scale boundaries was impacted (both positively and negatively) by the use of NLDASE land surface states. This in turn had noticeable impacts on severe weather diagnostics generated from the model output

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Acknowledgements:

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